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TABLE OF CONTENTS.

	PAGE.
ORIGINAL ARTICLES AND SELECTIONS:	
Radiation of Atmospheric Air. PROF. C. C. HUTCHINS	529
Atmospheric Radiation of Heat and its Importance in Meteorology. PROF. CLEVELAND ABBE	537
Wilde's Magnetarium. PROF. FRANK H. BIGELOW	552
Method in Our Winter Temperatures. H. GAWTHROP	560
On Acclimatization. ROBERT W. FELKIN	564
CURRENT NOTES:	
Corrigenda	575
Maury's Physical Geography	575
Royal Meteorological Society	576
EDITORIAL NOTE	578

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THE AMERICAN
METEOROLOGICAL JOURNAL

VOL. VIII. ANN ARBOR, MICH., APRIL, 1892. No 12.

ORIGINAL ARTICLES.

RADIATION OF ATMOSPHERIC AIR.

BY PROF. C. C. HUTCHINS, BOWDOIN COLLEGE, BRUNSWICK, MAINE.

We learn from the researches of Tyndall that the radiation from heated air streaming from about a copper ball heated to near redness was just detectible, but scarcely measurable with the most delicate apparatus then in existence.

He was also able to show that other gases, under like conditions, radiated, some to a much greater extent than air, and he formed a table in which the different gases experimented upon stand in the order of their radiating powers. This at present comprises about the sum of our knowledge of this important matter. The recent invention of several forms of extremely delicate heat measuring apparatus now enables us to deal successfully with quantities of heat so minute that the ordinary thermo-pile gives no indication of their existence.

The apparatus used in the following investigation is something of an improvement upon that formerly here devised and described (Proceedings American Academy, Vol. XXIV), which improvement has been effected by the substitution of a junction of the bismuth antimony and tin alloys in place of the iron-nickel couple formerly employed.

By a peculiar method of casting these alloys into thin leaves, it is possible to give them a certain amount of temper by which their tenacity is considerably increased, so that by skill and patience they can be worked into bars as small as 0.002 c. m·

thick and 0.03 c. m. wide, more difficulty, however, being experienced with the alloy of bismuth and antimony.

To avoid too many accidents, the bars in use are made a little stouter, about 0.003 c. m. thick and 0.05 c. m. wide, and are united to a very thin disc of copper foil 0.1 c. m. to 0.2 c. m. in diameter.

Such a junction has, when the component bars are each 0.5 long, a resistance of four or five ohms, and consequently the galvanometer has been rewound to about the same resistance. The result is an improvement in the sensitiveness and steadiness of the apparatus.

On account of the peculiar conditions under which we must work in determining the radiation of air, we seem practically confined to Tyndall's method, using a moving mass of air, inasmuch as gases are nearly transparent to the rays from all solid bodies at ordinary temperatures. We can, however, improve the method in detail, making use of a moving column of air hotter, but at the same pressure as the surrounding atmosphere, and moving at such a rate through it as to preserve definite and measurable dimensions. The following experiments deal entirely with air in its ordinary condition, neither purified nor dried. Little would probably be gained by using purified and dried air, for, as will be seen later, the radiation is mainly from the surface of contact between the hot and cold air, when more or less mixing must take place, so that the loss of heat from contact of hot and pure air, and cold and impure air, would in most respects be a less definite problem than that of the radiation from the ordinary air of homogeneous, even if of somewhat variable and uncertain composition.

Variation in composition causes great and rapid alterations in atmospheric radiation, and as we cannot allow for the variations, the only remedy seems to be to work rapidly when the conditions are favorable.

It has in fact been learned, at the cost of much time, that nothing can be gained by working under any but the most propitious circumstances. We must have nearly constant temperature and humidity, absence of wind, etc., if we are to expect consistency in observations made at even as short an interval as an hour. However, we have forcibly brought to mind the remarkable power that slight variations in the ordinary composition of the atmosphere have in altering its heat radiating properties.

APPARATUS.

A galvanized iron pipe three feet long, two and one-half inches in diameter, is supported at an angle of about forty-five degrees, and heated by one or more Bunsen lamps placed underneath. A large hole is made, near the bottom of the pipe, for the entrance of air, and when the pipe is heated a strong current sets through the tube and is discharged at the top.

To cut off air currents from the outer surface of the pipe, tin screens are made to surround it and move with it. The upper opening of the pipe is furnished with a nozzle of lead, presenting an opening one c. m. by three c. m. By burning, touch paper at the bottom of the tube, the lamps beneath being lighted, the shape of the column of air from the nozzle can be inspected at leisure, by reason of the dense smoke that issues with it, and by filing the throat of the nozzle it can be given such a shape that the column of heated air will preserve uniform dimensions for a considerable distance from its exit. After the lamps have been lighted for twenty minutes, the temperature of the air becomes constant, and changes but slightly for hours at a time.

The lower end of the tube is supported upon a pin, thrust across its diameter, so that while the bottom of the tube remains fixed, the remainder can be moved in a vertical plane by a pull upon a string, the tube falling back by its own weight when the tension upon the string is relaxed.

The thermo-pile points continuously to a large copper Lislie cube containing water at the temperature of the room, and furnished with a thermometer divided to 0°.1. When the observer at the galvanometer releases the pipe, it falls to such a position that the hot air streams in front of the opening of the thermo-pile at a distance of 3 c. m., causing a deflection of the galvanometer needle, after which the tube is raised by the string attached, the heated air now being discharged high above the opening, leaving the apparatus unaffected save by the radiation of the cube.

The breadth of the column of air is sufficient to fill the opening of the thermo-pile and leave a wide margin on either side.

For finding the instrumental reduction factor, a long, thin copper tank is provided, which may contain water a few degrees above the temperature of the room.

This tank is pushed between the stationary cube and the thermo-pile by an assistant, and withdrawn again at a signal from the observer at the galvanometer. It is furnished with a delicate thermometer which can be read to 0°.01.

READING GALVANOMETER.

Both the forward and backward swings of the needle are observed, and the mean of these constitutes a single observation, the mean of five or ten observations comprising a set. The sensitiveness of the galvanometer has been frequently changed to suit the conditions of experiment by changing the position of the controlling magnet. The period of the needle has always been kept less than ten seconds.

REDUCTION FACTOR.

The instrumental reduction factor is the amount of heat in small calories per second, from a surface that fills the aperture of the thermo-pile, necessary to give a deflection of one division of the galvanometric scale.

The reduction factor is always obtained one or more times each day, and is considered as applying to that day's observation only. It is found by observing the deflection produced by the warm copper tank, coated with lamp-black. The amount of heat per degree of difference per sq. c. m. per second for the difference of temperature between the tank and cube is found from the equation: $x = 0.000238 + 3.06 \times 10^{-6} - 2.6 \times 10^{-8} t^2$ (Proceedings Royal Society, 1872, p. 93).

The instrumental constant $c = \frac{x}{d}$ where d is the galvanometer deflection per degree of difference in temperature between the cube and tank.

RADIATION OF AIR.

Measures for finding the absolute radiating power of a column of air one centimeter thick at a temperature near 100° were made upon eight days. The results of each day's work were fairly satisfactory, but there was no sort of agreement between those of separate days.

A preliminary experiment upon the effect of humidity, made by measuring the radiation of the air in its ordinary state, and then again after letting steam into the room from the heating pipes, showed that the radiation increases with the amount of moisture in the air, confirming the result reached by Tyndall.

The readings of the barometer, and of the wet and dry bulb thermometers were thereafter recorded. But even after making a very sensitive wet and dry bulb apparatus, using two thermometers reading to 0°.01, and swinging the whole from the ceiling like a long pendulum, to the same level as the air entrance to the heated tube, I was unable to make out the exact connection between the heat radiated and the amount of moisture contained in the atmosphere. The utmost care was used and every precaution suggested by experience observed, but after more than a month no result beyond what was given in the preliminary experiment was reached. Notwithstanding the failure to establish a connection between the absolute amount of moisture and the radiation, the tabulated results show a striking connection between the relative humidity and the radiation, as is exhibited in the following table:

A	B	M	N	t—t′	f′	h
Oct. 20....	76.16	14.7	15.6	88.2	90.	0.000002562
Nov. 7....	76.41	16.1	23.9	89.0	40.	1189
Nov. 9....	76.76	16.7	22.8	88.7	50.	1273
Nov. 10....	76.76	10.0	13.9	84.0	57.5	1559
Nov. 11....	76.19	14.4	17.3	84.5	71.	1812
Nov. 11....	75.80	18.9	20.4	87.7	85.5	1986
Nov. 12....	75.99	14.0	17.9	88.3	62.5	1597
Nov. 13....	76.38	13.6	19.4	82.6	47.	1513

A is the date.
B is the baromotric reading.
M is the wet bulb.
N is the dry bulb.
t—t′ is the difference of temperature between hot air and cube.
f′ is the relative humidity.
h is the absolute radiation.

It will be seen that h increases quite regularly with f′, though the plotted observations do not lie well enough upon any smooth curve to enable us to assert the law of connection, which law it would be difficult to deduce without the means of controlling the presence of other accidental constituents of the atmosphere; such as carbonic acid and gases resulting from the decomposition of dust coming in contact with the heated tube. That these accidental impurities have a very great influence, is shown by the following experiment:

On December 7, the mean deflection produced by the air column at 120° was 64 scale divisions. A small amount of pure dry carbonic acid gas was allowed to mix, a bubble at a time, with the air at the entrance of the heated tube. The deflection rose to 140 or more than doubled.

When a very small amount of illuminating gas was mixed with the air, the deflection was too great to be recorded on the scale. As it is impossible at present to allow for the presence of these impurities, or even for the aqueous vapor, in assigning a value to the absolute radiating power of atmospheric air we are obliged to employ an average result obtained from several days' observations.

The following table presents the measures made on six days after considerable practice had been had with the apparatus.

The observations were made at four or more different temperatures of the air column, with a view to learning the law connecting the heat radiated and the temperature. (See table II.)

Upon plotting each day's observations separately, using the value t—t′ as ordinates, and the corresponding values of h as abscissas, we find that in every case the observations are represented by a straight line. Whence we deduct that in the case of air within the limits of temperature here employed, the increase of radiation is proportional to the increase of the temperature. This relation will doubtless be found true of other gases, and to apply to a wider range of temperatures. The mean equation of the six sets of observations given in the table is:

$$h = 0.000001133 + 0.00000000711\ (t - t')$$

which may be taken as fairly representing the radiation of air in an ordinary room under average conditions, the sheet of air being one centimeter thick.

a	b	f	c	t—t′	g	h
Nov. 23.....			$\bar{4}.741067$	53.7	18.42	0.000001889
				77.6	29.9	2123
				89.3	36.4	2246
				119.0	59.7	2763
				167.5	93.8	3085
Nov. 26.....76.3		7.89	$\bar{4}.714927$	53.0	14.2	0.000001390
				80.0	27.0	1751
				86.0	29.2	1761
				96.5	35.5	1908
				138.0	64.0	2453
				167.0	92.5	1908

a	b	f	c	t—t′	g	h
Dec. 4.....	76.0	6.50	$\bar{3}$.014392	53.0	10.37	0.000002022
				67.5	14.9	2282
				100.0	24.3	2511
				145.0	39.9	2845
				188.0	62.5	3437
Dec. 6.....	75.5	4.76	$\bar{4}$.440807	64.3	32.8	0.000001407
				83.5	40.4	1305
			$\bar{3}$.166587	84.0	9.0	1572
			$\bar{4}$.440807	115.0	57.5	1380
				152.0	87.0	1574
			$\bar{3}$.166587	185.0	21.6	1713
Dec. 7.....	75.3	6.16	$\bar{4}$.339524	47.0	28.3	0.000001393
				87.5	58.6	1464
				113.0	74.2	1435
				153.5	103.5	1473
				205.0	147.6	1573
Dec. 8.....	76.6	5.08	$\bar{4}$.393008	46.0	20.5	0.000001102
				82.0	43.0	1299
				104.0	51.9	1234
				160.0	106.5	1637

a is the date.
b is the barometer reading.
f is the absolute humidity.
c is the log reduction factor.
t—t′ is the difference in temperature between air and cube.
g is the mean galvanometer deflection.
h is the absolute radiation of air.

The amount of heat lost each second from each square centimeter of surface for each degree of difference between the temperature of the air and of the surroundings, the sheet of air being one centimeter thick.

EFFECT OF THICKNESS OF RADIATING COLUMN.

It was noted at the outset that the galvanometer deflection was not proportional to the thickness of the heated column of air.

A flat sheet iron pipe was made, 100 centimeters long, 10 centimeters wide and 2.5 centimeters thick. This pipe was

substituted for the one previously used. The air exit was from a pair of jaws, one fixed, one movable, so that the thickness of the air column at its escape could be regulated at pleasure. Measures with this apparatus were made on eight days. The results were recorded as the amount of galvanometer deflection per degree of t—t'.

With openings less than one centimeter no difference in the amount of radiation can be detected. With larger openings, a small increase is observed.

The results of six determinations, distributed over four days, are here given:

	c. m.	c. m.	c. m.	c. m.
Opening	0.5	1.	2.	3.
Deflection per degree	0.193	0.195	0.245	0.259

We observe that radiation is very largely from the surface of contact between the hot and cold air, which seems to indicate that a heated gas absorbs all or nearly all those rays that it itself emits, and that radiation takes place only when there is a fall of temperature within the limits of molecular action.

WAVE LENGTH OF RAYS.

It would probably be hopeless to undertake a prismatic analysis of the rays from heated air. We can, however, get a suggestion as to the length of these waves from their behavior towards an absorbing medium. A very pure plate of quartz 0.5 centimeters thick was placed over the opening to the thermopile. With the air at 100° no deflection could be obtained, and even when the temperature was raised to 200°, it was decided after many trials that there was no measurable effect. Without the quartz plate the deflection was 151.

The quartz plate allows ninety-three per cent. of the sun's rays to pass it, thirty-one per cent. of rays from red hot platinum, and three per cent. of rays from lamp-black surface at 100°, being in a manner pragressively opaque to waves of increasing length. The waves from heated air must therefore be of great length, since they seem incapable of penetrating the quartz in any measurable degree.

ATMOSPHERIC RADIATION OF HEAT AND ITS IMPORTANCE IN METEOROLOGY.

By Professor Cleveland Abbe.

(1.) It is evident that our planet, considered as a whole and on the average of many years, loses all the heat that it receives from the sun, but all the details of this process have not yet been completely worked out. Fourier, Poisson and their disciples have treated of this radiation in the most general manner; Melloni, Tyndall, Langley and their followers have gone into some of the details as to character and quantity. These physicists have served to awaken meteorologists to the necessity of carefully distinguishing the influence of the absorption and radiation by the soil, the vegetation, the snow, and the ocean respectively; even as to the atmosphere itself we have to distinguish the absorbing and radiating powers of the dry air, of the clouds or haze, and of the dust respectively.

(2.) Heat is thrown into the atmosphere not only by conduction and convection from the immediate surface of continents or oceans, but the radiant heat from these surfaces is in part directly absorbed (just as is solar radiation) by the atmosphere and in part transmitted to outer space. All of the immense quantity of heat thus communicated to the whole atmosphere (viz: 50 per cent. of the direct solar radiation, plus about 50 per cent. of the specular reflection from the earth and water, plus all of the convection from the surface of the earth and ocean, plus a large per cent of the radiation from the earth's surface) must be lost through a process of radiation from the atmosphere as distinguished from radiation through the atmosphere; judging from the known values of these items one would *a priori* conclude that this radiating power of the whole atmosphere must average about 0.5 calories per minute per square centimeter of its outer surface.

(3.) At first thought one would say that, according to Kirchhoff's law any radiation from a mass of air must be of such a quality as to be immediately absorbed by the adjacent air in the attempt to pass through it and therefore cannot escape into space except when radiated by the very outermost layer of the atmosphere. But in reply to this we note that the processes of radiation from and absorption by layers of air within the atmosphere depend (like those of conduction) upon differences of

temperature and possibly on differences in density, consequently it is quite possible that heat radiated from the warmer and denser, moister and dustier layers below may in part escape directly through the upper layers into æthereal space; that portion of this heat which is absorbed by the upper layers will in turn, by a similar process, escape from them.

(4.) The fact that some such process is going on in the atmosphere has, I presume been recognized by many, although the published expressions in regard to it are generally very indefinite. It is almost invariably the case that the cooling of the air at night is attributed to the radiation of heat from the earth, and the fact that the surface of the soil becomes cold is quoted as an evidence of this action. But it can easily be shown numerically that the nocturnal conduction of heat between the surface of the earth and the air above it can only affect a very thin layer of air during the twelve hours of night time (3 meters according to Maurer) and that there must be an appreciable radiation from the air itself.

(5.) On this whole subject the writings of Dr. Julius Maurer offer us some valuable formulæ and data; especially has he been the first (see Schweiz. Met. Beob., 1885, Vol. XXII, Append. V, Zurich, 1887,) to give us an approximate value of the co-efficient of radiation of a cubic centimeter of air. This co-efficient he deduces from the ordinary meteorological observations of the temperature of the air at night time as given by the ordinary screened thermometers. Maurer finds that the cooling of the free air during night in the lower layers of the atmosphere and on the average of the whole year, namely without distinguishing between cloudy and clear weather, or calms and winds, proceeds as though a cubic centimeter of air gives up to an enclosure, 1° C. cooler than itself, 0.000 000 7 gram-calories per minute. Now the specific heat of air under constant pressure is 0.2377 and the density of the air to which Maurer's co-efficient pertains is about 0.00129 or 1-773 of water. We may therefore convert his co-efficient of radiation in absolute calories into a co-efficient of cooling in Centigrade degrees whence it results that the cubic centimeter of air within such an enclosure cools by radiation at the rate of $0.000\,000\,7 \times 773 \div 0.2377 = 0.0023$ degrees Cent. per minute or 0.138 C. per hour.

Maurer finds indications that this co-efficient is larger in summer and smaller in winter. The above average value results from observations of temperature for many years at

St. Petersburg, Prague, Berne, Toronto and Barnaul and may be considered as belonging to air that has an average pressure of 750 millimeters, a temperature of 5° Centigrade is nearly saturated with moisture, and contains the average amount of dust and aqueous particles that belong to the air of those stations. Maurer especially notes that the co-efficient thus found is larger than belongs to pure, dry air on account of the solid and liquid particles contained in the ordinary atmosphere and participating in the radiation. He further states that similar computations based on observations made at the high stations, St. Bernard and Santis, give a co-efficient about fifteen per cent. smaller.

(6). It is evident from Tyndall's observations and those of Angstrom and others that this co-efficient must also vary with the chemical nature of the gases contained in ordinary air and although it is therefore of a very indefinite nature, yet we need to know its probable limiting values in order to understand the extent of the influence of atmospheric radiation upon meteorological phenomena. On this account I have applied Maurer's formulæ to other meteorological observations, and during the past three years have mentioned to several physicists the desirability of the direct determination of this co-efficient by ordinary laboratory methods. I am therefore much pleased that Professor Hutchins has been able to make a direct experimental response. The values deduced by him are considerably larger than those given by Maurer, as was to be expected, because Maurer's computation considers only the average radiation during cloudy as well as during clear nights, and also because it assumes that the convection during windy nights has not obscured the simple effect of radiation. Furthermore there is a possibility that the heated metallic tube of Professor Hutchins may have given off an extra quantity of dust or of gaseous compounds, all of which would increase the apparent radiation. But although neither of these determinations represents pure, clean, dry air, and although both must at present be considered only as first steps in our knowledge, yet they give us invaluable indications of the possible dimensions of an important fundamental constant in meteorology.

(7). The importance of this subject in the study of the mechanics of the atmosphere may be enforced by the following consideration of the progress of our knowledge.

(*a*). Espy having reasoned his way up to the conclusion that

rising air cools by virtue of the work done by it in its expansion against the surrounding pressure also clearly stated that descending air is warmed by compression (*i. e.*, by the work done upon it) whence it is able to dissipate any fog or cloud that it contains and becomes perfectly clear; inversely, cloudless skies, whether in small patches or large regions, demonstrate in general the prevalence of descending air. The further development of Espy's principle gave rise to what is called his latent heat or condensation theory of storms, the items of which are briefly as follows; ascent is due to buoyancy; cooling is due to the work of expansion incident to the ascent; when cooling has brought the air to the dew point and to precipitation then the latent heat is liberated and the cooling is checked, but the relative buoyancy of the ascending air is increased, the indraft and updraft increase and the storm grows; when the inflow is prevented, or when it brings dry air instead of moist air, then the condensation of moisture stops and the storm subsides.

(*b*). Ferrel worked out, from the point of view of hydromechanics, the theory of the circulation of air in cyclones and in the surrounding peri-cyclonic region; he also developed the mechanics of cyclones with cold centres; he then showed how ordinary areas of high pressure and cold air (which Galton in 1863 first called anti-cyclones) may result from the inter-action of two or more peri-cyclones; he mentions without further development the radiation of heat from the air, but gives greater weight to the conduction to the ground and thus explains the inversion of temperature in the clear still air of winter. Much of this was done before the publication of the weather maps of the Signal Service, or, indeed, of any European weather bureau. Ferrel subsequently developed the thermodynamics of the condensation theory of Espy and showed its excellent agreement with all the known facts of local storms, hence it was assumed to also apply to the large storms or areas of low pressure.

(*c*) Hann, having shown that the föhn wind is a rapidly descending mass of air whose warmth is due to an initial rain or snowfall with the evolution of latent heat and to the subsequent rapid compression of the air, follows this up by the study of the slowly descending movements as exemplified in the European area of high pressure of 1889, Nov. 11–23. He finds, as Ferrel had done before him, that in the high areas the temperature at

a few thousand feet altitude is higher than that at the surface of the ground; he concludes that the average temperature for a depth of 3,000 meters is somewhat higher in an anti-cyclone than in a cyclone. Hence, Hann throws doubt upon the idea that an area of high pressure with cold air near the surface of the ground only, is really a mass of descending cold air; like most others he also explains that the coldness of the lowest stratum of air under a clear sky is due to radiation from the surface of the ground. Hann's array of data requires that we now consider more closely the mechanical theories of atmospheric motion; these have usually assumed an incompressible atmosphere of about 8,000 meters in depth.

(8) Some features of recent researches in the mechanics of the atmosphere may be presented as follows: A comprehensive study of fluid motions shows that air and water alike may be forced to ascend without being warmer and lighter or to descend without being colder and denser than the surrounding fluid. The currents and whirls behind any obstacle in streams of air or water are almost wholly independent of differences of density and are caused by differences of pressure as modified by simple kinetic laws. The uprush of water at one place and its downrush, as a whirlpool, at another place in a swift stream is a vortex phenomenon in which temperature and density have no part. The rise of the surface of a river at any bend in the channel or at the junction with a tributary stream is a kinetic phenomenon; so also is the resulting surface overflow to the right and left of the channel; so also the slow spiral circulation that goes on, in consequence of which the surface water flows from the centre out to the banks of the river, then down to the bottom of the channel, and thence up to the swift surface and back to the banks again.

We must expect to find similar phenomena in the atmosphere where, corresponding to the general current of the river, we have a general circulation of air due to the greater warmth of equatorial air and to the swift diurnal rotation of the whole atmosphere about the polar axis.

(*a*) Ferrel was the first to show that the tropical belts of high pressure are due—not to local cool air or to local density but—to the inter-action of pressures and that they would exist if the atmosphere were a mass of incompressible fluid; they may be affected to some degree by various forms of resistance, they may also be affected by temperatures due to local radia-

tion and convection, and also by thermodynamic relations, but all these are minor incidents subordinate to the action of the hydro-dynamic laws that bring them into existence.

(*b*) Ferrel maintains that areas of high pressure with cold anti-cyclonic winds give evidence of originating with upper currents of air such as those that are conceived to flow out from great cyclonic areas and be then whirled toward each other; Ferrel's reasoning would justify his conclusion that there is only sufficient energy in those whirls that are due to the general circulation between the equator and the pole, to generate very moderate, high and low pressures, but not the great barometric depressions and elevations that characterize the low and high areas. He therefore looks to the latent heat of the precipitated vapor as not only maintaining the lows but furnishing the energy that enables these to overflow as peri-cyclones which by interference among themselves give rise to the high areas.

(*c*) It has been shown by Prof. Finger, of Vienna, that westerly winds have a tendency to rise above the earth's surface due to their excess of centrifugal force, while easterly winds having a deficiency tend to press down upon the earth's surface; but these effects are inappreciable in our barometric measurements and cannot be quoted as efficient mechanical causes for the production of high or low pressure.

(*d*) Besides the horizontal movements and whirls, Helmholtz has studied what may be called the vertical whirls or the general vortex motion of which the ideal case is an atmospheric vortex ring surrounding the earth at the equator and moving, as a whole, poleward. If such a ring of incompressible air, is to retain its energy as it moves northward and is to contract as the circles of latitude diminish it must exhibit far greater velocities than are observed, therefore some way must exist by which it loses its energy. If, however, by reason of the irregularities of the earth's surface such rings become broken up, each part will revolve as an independent ring having an inclination to the earth's surface and by the interferences and mixtures of these rings the motions may become reduced so as to agree with the observed winds. From this point of view all movements from the equator carry rapidly revolving air into regions where the rotation is less rapid and such air must rise above the earth's surface, whereas, for motions toward the equator the air must descend and hug the earth's surface, thereby acquiring the

greater speed of rotation that belongs to low latitudes on forming local high pressure areas.

(*e*) We see, therefore, that whether we study horizontal or inclined, or even vertical whirls in the atmosphere, we are alike brought into the presence of ascending and descending motions which the air is forced to take for purely kinetic reasons. So long as we, with the above mentioned authors, consider only the ideal case of a homogenous, incompressible, dry atmosphere having an average depth of about 8,000 meters and whose temperature at any point depends upon its absorption of solar radiation and upon its warming up by conduction, we have perhaps no need of a special study of the thermodynamics that is so important in the real atmosphere of compressible air. For such a problem it may therefore be sufficient to assume, as seems to be implied by Ferrel, Hann and Helmholtz, that the air loses heat by the simpler process of conduction to the cold earth. But when we investigate the real atmosphere on the basis of actual observations we find that the thermodynamics of the compressible air adds a most important feature.

(*f*) We have thus far concluded only that local areas having a slight excess or deficiency of pressure would be maintained if the atmosphere were perfectly dry and were an incompressible fluid; but if the air is moist and is compressible, then the regions of diminished pressure give rise by Espy's thermodynamic process, to the formation of clouds and rain which form temporary and local episodes in the general motion. Such condensation of moisture especially tends to form in the rising part of the circulating air, and thus co-operates with the general mechanism to produce spiral, ascending currents that intensify and prolong the meiobars, and therefore the overlapping peri-cyclones of Ferrel or vortices of Helmholtz, thus eventually intensifying the pleiobars.

(*g*) According to these views the primary factors in the origin and maintenance of local rains, water-spouts, thunderstorms and tornadoes are local buoyancy, expansion, thermodynamic cooling, condensation and latent heat. On the other hand in extensive storms of the temperate and arctic zones it is the slight depression, due to a whirl in the general circulation, that determines where a storm or low area will originate. Finally, in tropical hurricanes the general circulation must decide whether an initial local disturbance shall die away or shall be fed and developed into an extensive hurricane.

(*h*) So mobile is the air that two conflicting currents cannot produce any considerable excess or deficiency of pressure, and such a mechanical heaping up, or compression, as would produce a barometric gradient of 0.1 millimeter per degree is immediately followed by a movement in the air that will relieve the excess. Therefore, as Ferrel distinctly shows, we must not expect that any obstruction to the moderate currents of the general circulation can explain such great barometric elevations as occur in the high areas of the United States or Europe. A slight mechanical excess of pressure may possibly initiate a high just as a deficiency does a low, but the further development of the pressures must depend upon other considerations. Among these latter, Ferrel, so long ago as 1856, showed that just as the low pressure depends upon the centrifugal forces due to a cyclonic whirl, so the high pressure depends, at least in part, upon a centripetal force due to an anti-cyclonic whirl.

Again, Ferrel has stated that if the cold of the lowest layer in the high area extends upward, then the weight of this dense air would help to explain the high pressure. This suggestion needs careful consideration in view of the observed presence of warm air in the upper layer where cold air was supposed to exist. Although Ferrel maintained that the air in the high areas must on the average be colder, and therefore be descending by virtue of its own gravity, yet he has not made clear the details of the process by which descending air can become cooler and denser.

(*i*) The existence of warm air above the cold layer near the ground has long been recognized for moderate elevations during clear nights; its influence upon the atmospheric refraction is apparently often very notable in astronomical observations. The fact of its existence has also been brought out, even for the day time, by many balloon observations, notably those of Glaisher in England, and of Mr. Hammon in the United States (see the *American Meteorological Journal*, February, 1891). To the early observations of the Signal Service at Cheyenne, and subsequently at Pike's Peak, as displayed on the daily weather maps, we owe the knowledge, that has these twenty years been public property in the United States, that warm air exists above the western side of our great cold waves. Ferrel, in his "Recent Advances," explains this upper warm layer as due to the compression of the descending air which eventually flows horizontally above the lowest layer, which latter is composed of air that has cooled by conduction to the cold

ground near which it lies quietly resting; he states furthermore that an additional cooling is due to the evaporation of moisture from the soil and also to the "radiation of the air," but no special importance is attached to the latter factor nor to the fact that often during daylight sufficient solar heat does not penetrate into the lowest stratum to dissipate the haze and fog that is often formed during the night time. Hann has presented the details of the continued existence of such a warm layer for many days over the midst of the European area of high pressure of November, 1889; his suggested explanations, so far as they go, agree with Ferrel's.

(*j*) But the slow horizontal flow, the evaporation of moisture from the ground and the conduction of heat to the ground by the air within a few meters distance explain only a portion of the observed phenomena. We need a thermal process that shall do for the high area that which the condensation of vapor, and its precipitation as rain or snow, does for the low area. I have been accustomed to explain this abstraction of heat in a general way as due to the warming of the air by compression and the loss of this evolved specific heat by direct radiation, but the numerical application of this idea was hindered at first by our ignorance of the co-efficient of radiation and eventually by the very small co-efficient deduced by Maurer. The larger co-efficient of Hutchins and a conviction that Maurer's value is too small, lead me with some confidence to ask the attention of meteorologists to the present study from which we find that we need not hesitate to accept Espy's conclusion that a cloudless blue sky demonstrates that descending movements are present and are more efficacious than any minor ascending movements that may be present. The existence and qualitative influence of radiation from the air was discussed by me with Ferrel before the publication of his "Recent Advances" and admitted by him as a possibility, but in the absence of any knowledge as to the co-efficient of radiation Ferrel seems to have decided to mention the subject only in a general way.

(9) If the air itself radiates its own heat then the temperature of an ascending or descending mass, or the general law of the diminution of temperature with altitude must depend upon the time during which radiation has been progressing and this duration will enter as an exponent in the analytic formula. Again the enclosure to which this heat is radiated, as imagined in connection with Maurer'r co-efficient, is on the average 1° C.

cooler than the radiating mass, therefore, its dimensions may be calculated and it appears that, near the earth's surface, the lower portion of such a sphere is cut off and is replaced by the cold ground which is equivalent to diminishing the size of the sphere or increasing the rate of radiation; a similar consideration obtains at the outer limit of the atmosphere; in general the radiation of a descending mass causes it to cool least rapidly when at a medium altitude above the ground or in the midst of the atmosphere.

As for conduction between the earth and the air it is easily recognized, as Maurer has shown, that this has an inappreciable influence during twelve hours at three meters above the soil or during forty-eight hours at six meters; it can only become moderately important for calm air during long arctic nights. As concerns convection of heat by currents rising from the earth this will directly affect the dry, cold, clear, calm air in the midst of high pressures only up to a moderate altitude, say 1,000 meters, and that only in the warmer part of the day because the rising currents are rapidly cooled by mixture and cease rising at an altitude whose limit in such weather is usually defined by a thin layer of dust and haze. Up to this altitude therefore atmosphere radiation of heat, during twenty-four hours of day and night, may be partially compensated by convection during sunshine, but this limit is much lower for still air lying over ice, snow or water. As concerns the cooling due to evaporation, this can be computed from the known amount of evaporation and is a very small quantity for the cold air over the land north of latitude 50, where our high areas form.

Therefore the factors that principally affect temperature in extensive areas of high pressure are: 1. The direct absorption by the air of the solar radiation. 2. The direct radiation by the air of its own heat. 3. The thermal changes due to changes of barometric pressure in the radiating mass which are themselves due principally to its descent in the atmosphere.

(10) With regard to the direct absorption of solar radiation, the bolometric researches of Langley show that the general co-efficient of transmission of solar radiation through the atmosphere varies from about 0.8 in the red and 0.6 in the yellow to 0.4 in the violet and averages approximately 0.6 for the whole spectrum. These figures relate to the general absorption of a zenithal ray passing through the whole atmosphere down to the

layer whose elastic pressure is 760 mm. and give no idea of the special absorption of specific wave-lengths that may radiate from the sun or the earth. The corresponding transmissions for the same rays, when they have penetrated only down to the layer at 10,000 meters altitude or down to a pressure of 217.4 mm., are 0.939 in the red, 0.864 in the yellow and 0.769 in the violet; hence 0.14 and 0.26 and 0.37 are the respective fractions of the original heat absorbed from the ray in its passage through the lowest 10,000 meters of the atmosphere. Now the relative thermal intensities of these radiations are respectively 68, 108 and 52 and for the present approximation we may consider that about twenty per cent. of the original incident solar heat (three gramcalories per square centimeter per minute) is distributed by absorption along the 10,000 meters of this lower path. Therefore, during the slow descent of air in the midst of a high area the principal external source of heat is the direct absorption of solar heat and this, at its maximum for zenithal rays, can in the lower atmosphere only amount to an absorbtion of $0.20 \times 3 \div 10{,}000 \times 100 = 0.000\,000\,6$ calories per minute per cubic centimeter of air; in northern latitudes and on the average of the ordinary six to twelve hours of sunshine the absorption becomes much less; for Central Europe, in November, the average for the whole duration of sunshine would be less than 0.000 000 2 calories per minute.

(11) As opposed to this gain of heat we have only the loss by direct radiation which is, according to Maurer, expressed by 0.000 000 7 gramcalories per minute per cubic centimeter (or 0.000 6 calories per kilogram mass) of air when the surrounding enclosure has an average temperature 1° C. less than that of the radiating mass.

Without discussing the nature of the diffusion of heat by radiation of conduction within a gas we remark that Maurer's co-efficient of radiation relates, strictly speaking, to a mass, not to a volume; we may plausibly assume that the unit mass of air has the same co-efficient whatever the density of the air, at least within a pretty wide range, therefore it will follow that the rate of linear descent within our atmosphere that produces a rate of compression and dynamic warming sufficient to compensate for the cooling by radiation must be greater at high altitudes than at low ones.

Dusty, hazy or moist air, as also the ammonia and the hydrocarbons or the carbonic acid ordinarily present in the air, have

somewhat larger specific heats than those for clear dry air, but they also all have larger co-efficients of radiation, so that their cooling by radiation is more rapid than that of pure, dry air.* This atmospheric radiation, moreover, continues day and night, and is much more effective in direct cooling than the solar radiation is in direct warming. Since the loss by radiation may, according to Professor Hutchins, be far greater even than this, and since Maurer's figures represent only an average for all kinds of weather we are fully entitled to at least the general statement that the cooling by radiation is to only a very slight extent offset by the direct absorption of solar heat, and that its co-efficient may vary from the minimum value of 0.°1 Centigrade per hour, as previously computed, up to an unknown and much higher limit.

The actual rate of cooling varies approximately as the difference of temperature of the radiating mass and its enclosure, and this is probably least in the mid-atmosphere as before stated and must increase as the mass sinks to the region where the colder terrestrial surface becomes an integral part of its enclosure and especially when the effect of conduction to that surface is superadded.

(12) The thermodynamic warming by compression takes place at the rate of about 1° Centigrade for each 100 meters of descent. As the co-efficients of absorption and radiation are uniform for equal changes in barometric pressure as we descend in the atmosphere, the thermal effects therefore vary more rapidly for a given change of altitude at low levels than at high levels, therefore in the early stages of any descending motion the downward movement may be accelerated, but there will be a tendency towards a steady rate of descent, such that the loss of temperature by radiation exactly counterbalances

* A parallel process must take place in the solar atmosphere if we suppose the gases that ascend from the immediate surface of the sun to be at such a high temperature that all the chemical combinations ordinarily known to us are dissociated; when a mixture of such elementary gases in this highly heated condition ascends until by expansion it is cooled to the temperature at which chemical combinations are possible, then these take place and generally with an evolution of heat (the latent heat of combination). The continued evolution of this heat compensates for further cooling by expansion just as the latent heat of vapor operates in Espy's theory of storms; when, however, the combined gases have cooled by expansion and radiation as they ascend until the molecules of the new complex gases can form clouds of vapor there forms an outer layer of radiating cloud matter such as we call the surface of the sun. If the colder vapors, at this surface, are by any process drawn down or if by condensation they sink at a steady rate, they are again warmed up by compression, the descending gas becomes clear and may pass through the dissociation stages by absorbing a new quantity of heat radiated from the solar nucleus which heat is in turn to be lost by radiation in the subsequent ascension.

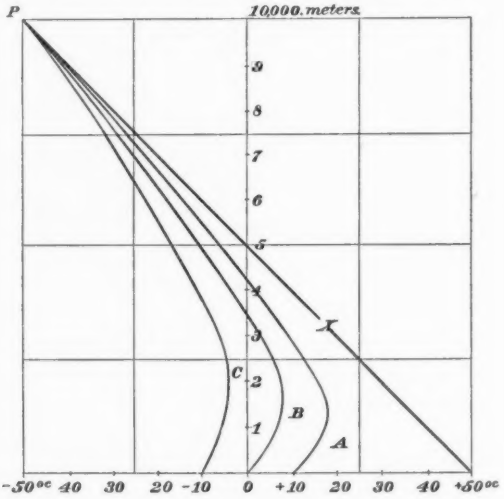
the gain by compression. If we accept Maurer's co-efficient and diminish this by a unit in the seventh decimal place in order to allow for the absorption of solar heat, as just calculated above, we have a resultant 0.000 000 6 gramcalories as the loss of heat on the average of twenty-four hours; this corresponds to a diminution of temperature of 2.88° Centigrade per day, and if this is to be compensated by compression it will require a descent at the rate of 288 meters per day; a more rapid cooling by radiation, such as is required by Hutchins' co-efficient, would require a proportionately rapid rate of descent. Such a thermodynamic compensation would bring about an uniform temperature at all altitudes in the descending air. The fact that in high areas air is warmer as we descend, down to a certain altitude, must therefore be held to prove that the air is descending faster than this compensation rate, just as it does in the case of the föhn.

The resulting rate of warming expressed in degrees Centigrade per 100 meters of descent is given by the formula; one less the quotient of 288 divided by the rate of descent expressed in meters per day. Thus if the descent is 144 meters per day the air will cool with descent at the rate of 1° Centigrade per 100 meters; if the ascent be 432 meters per day the air will be warmed up at the rate of 0.33° Centigrade per 100 meters. In the upper layers of the maximum area of 1889, as investigated by Hann, the air grew warmer at the rate of 0.38° Centigrades per 100 meters corresponding to a rate of descent of 457 meters per day; on the other hand in the lower layer, namely between 500 and 1,000 meters the air grew colder as the altitude diminished at the rate of 1.8° Centigrade per 100 meters, corresponding to a rate of descent for the air itself of 37 meters per day.

(13) These figures must for the present be considered merely as illustrations of the quality of the influence that atmospheric radiation must exert on the temperature and motions of the air. If the co-efficient of radiation of the upper air is less than Maurer's figure, or if the co-efficient for the lowest strata is as large as Hutchins' figures, owing to the abundance of dust and haze, or if, as is generally the case the enclosure is more than 1° cooler, then the numerical rates just given will need to be modified. In either case the general principle remains that on the average throughout the whole atmosphere the cooling by atmospheric radiation largely compensates for the warming by

compression and that in this way we must reconcile the hydrodynamic theories with the facts of observation so clearly set forth by Hann.

The compensating process here discussed is illustrated by the curves in the accompanying diagram which express the fact that if air starts at a height of 10,000 meters at P at a temperature of —50° C. and descends to the earth's surface adiabatically its temperature will be expressed by the straight line X and will be + 50° C. on reaching the earth's surface. But if it cool by radiation its temperature at any altitude will be represented by



Temperature and Altitude.

FIGURE I.

uch curves as A, B or C, whose curvature will depend upon the ates of radiation and descent. The apices of these curves or the regions where the increase of temperature with descent ceases and becomes a decrease will be nearer the surface of the ground in proportion as the co-efficient of radiation is smaller or the rate of descent is smaller and especially if the rate of descent diminishes with the time.

These curves agree with the general tenor of all observations on the temperature of the air, namely, that under a cloudy sky

the diminution of temperature with ascent is very slight and uniform; within a cloud the diminution is given by the laws of evolution of latent heat; above all clouds and in all clear air as in areas of high pressure the temperature depends upon the radiation of heat and on the thermodynamic changes of a compressible atmosphere.

(14) In addition to the cases recently under discussion between Ferrel and Hann there are other important problems in the mechanics of the atmosphere that are elucidated by the study of radiation.

(*a*) The general circulation of the atmosphere from the equator to the pole can only take place by virtue of the fact that the air which overflows from the equator and from the tropical highs actually loses its heat (not merely diminishes in temperature) and contracts as it cools. Radiation is the only efficient process capable of accounting for the great loss of heat that the atmosphere experiences. Although we are not yet able to state the average amount and law of radiation as dependent on temperature and pressure, yet it is easy to see that this must be known and must enter into our equations of condition before we can fully account for the phenomena observed in the general circulation of the atmosphere.

(*b*) The passage of a steady atmospheric current over a mountain range depositing rain and snow on the windward side, but descending as dry air on the leeward side gives rise to a standing wave such as may be seen above any obstacle in a rapid river. Thus kinetic energy is converted into static pressure and, therefore, on the leeward side under the summit of the wave down to the earth's surface there is a somewhat higher pressure than there would be in case no such current existed. The clear descending air by its dryness has also a slightly greater density than before at the same temperature and pressure, which adds somewhat to the barometric excess. The cooling by radiation annuls approximately the warming by compression and again gives increased density. These three factors therefore conspire to increase the pressure at the earth's surface and this is again further increased largely by the influences of the earth's rotation and the southward flow as explained by Ferrel and Helmholtz. This is the best explanation that I have yet been able to frame of the formation of the high areas and cold waves that move southeastward over Canada and the United States. I believe that I first stated my conclusion as to this

mèchanism when, in 1876, I had occasion to urge the importance of maintaining meteorological stations in Alaska. The reports from these stations as subsequently established as well as the international maps of the Signal Service served to confirm that view. The original current on the Pacific side of the Rocky Mountains may be due either to a special cyclone or to the general circulation of the atmosphere resulting in a standing wave whose summit is over the Mackenzie river; when the current temporarily ceases the summit and the high area die away and when it is strongest the high pressure is the greatest. Generally the original current may be considered as a temporary overflow from northern Siberia along the arctic circle to Alaska.

Washington, March, 1892.

P. S. — [As I finish this paper I perceive from the last number of the "*Meteorologische Zeitschrift*," that Dr. William Trabert, of Vienna, has repeated and confirmed Maurer's calculation of the co-effiicent of radiation. But the values (respectively 0.036 and 0.032 calories per hour per kilogram of air) thus deduced from meteorological observations can, as I have above stated, not be preferable to the direct experimental determination. Trabert gives the values of the annual average temperature of the enclosure towards which radiation is supposed to have taken place during the night, which values are between one and eight degrees centigrade below the temperature of the radiating mass.]

WILDE'S MAGNETARIUM.

By Professor Frank H. Bigelow.

I have already taken an opportunity to express my pleasure at the fair prospect opened to magneticians by the principles displayed in the construction of Mr. Wilde's Magnetarium. The general subject matter is so difficult and complex as to the phenomena manifested, it has so long bid defiance to all attempts to refer it to one, or even to a single set of originating causes, that the probability of reaching a satisfactory solution by any plausible method, is very welcome. The facts being taken for granted, on the evidence of his paper, the testimony of the magnetarium is that there is one intelligible analysis which appears to bring order out of chaos.

That some who have not seen the original work, may get an idea of the degree of accuracy attained by the apparatus, the following table has been compiled to show the parallelism between the observations on the secular variation of the elements in declination and inclination, and the indications read from the magnetarium.

In the case of London the readings are on the globe with its magnetism symmetrically distributed; in the cases of St. Helena and the Cape of Good Hope, the magnetism had been made asymetric by the application of iron sheets to ocean areas.

These figures are certainly suggestive. A captious critic might say that the series derived from observation and from the magnetarium are not identical, but exhibit only parallel types of curves. That they are similar curves is in itself a most important consideration, and points to certain fundamental principles inherent in the problem of the secular variations. To have secured an identity of curvature, would have been to reproduce in the magnetarium a perfect model which comprised all the peculiarities of the earth as a seat for mag-

London in Latitude 51° 28′ N.

YEAR.	DECLINATION.		INCLINATION.	
	OBSERVATION.	MAGNETARIUM.	OBSERVATION.	MAGNETARIUM.
1657	0° 00′	0° 00′		
1672	2 30 W.	6 00 W.		
1692	6 00	10 20		
1723	14 17	17 40	74° 42′ N.	74° 30′ N.
1748	17 40	21 0	.....	.....
1773	21 9	22 40	72 19	73 50
1787	23 19	23 35	71 56	72 25
1795	23 57	23 55	71 30	71 45
1805	24 8	24 10	70 27	71 10
1813	24 20	24 25	70 15	70 40
1815	24 27	24 28	70 11	70 32
1818	24 38	24 30	70 8	70 25
1820	24 34	24 25	70 5	70 15
1830	24 00	24 5	69 38	69 38
1858	21 54	23 0	68 20	68 0
1860	21 40	22 50	68 19	67 45
1865	20 59	22 30	68 8	67 28
1870	20 19	22 20	67 58	67 10
1875	19 41	22 10	67 48	66 50
1881	18 50	22 0	67 36	66 28
1887	17 49 W.	21 50 W.	67 26 N.	66 5 N.

Cape of Good Hope in Latitude—33° 56′, S.

YEAR.	DECLINATION.		INCLINATION.	
	OBSERVATION.	MAGNETARIUM.	OBSERVATION.	MAGNETARIUM.
1605	0° 30′ E.	.....		
1609	0 12 W.	0° 00′		
1614	1 30	1 10		
1622	2 00	2 50		
1675	8 00	12 50		
1691	11 00	15 20		
1721	16 25	19 40		
1751	19 15	23 10	43° 00′ S.	37° 15′
1768	19 30	24 35	44 23	39 50
1774	21 36	25 15	45 5	40 50
1780	22 16	25 50	46 46	41 40
1783	22 23	26 5	46 56	42 10
1788	24 4	26 35	47 12	43 00
1792	24 31	26 55	47 25	43 40
1818	26 31	28 32	50 47	49 10
1836	28 30	29 8	52 35	52 30
1839	29 9	29 15	53 6	52 55
1842	29 5	29 25	53 26	53 20
1845	29 7	29 30	53 44	53 50
1850	29 18	29 41	53 56	54 40
1880	30 00 W.	30 00	57 00 S.	57 55

St. Helena in Latitude —15° 57′ S.

Year.	DECLINATION.		INCLINATION.	
	OBSERVATION.	MAGNETARIUM.	OBSERVATION.	MAGNETARIUM.
1677	0° 40′ E.	1° 00′ E.		
1691	1 00 W.	1 15 W.		
1724	7 30	6 40		
1755	12 18	12 00		
1789	15 30	16 15		
1796	15 48	17 10		
1806	17 18	18 20		
1839	22 17	21 55	17° 55′ S.	18° 00′ S.
1840	22 53	22 5	18 16	18 10
1846	23 11	22 40	19 12	19 50
1880	26 0 W.	25 40 W.	29 00 .	29 40 S.

St. Petersburg in Latitude 59° 46′ N.

Year.	DECLINATION.		INCLINATION.	
	OBSERVATION.	MAGNETARIUM.		
1726	3° 15′ W.	4° 30′ W.		
1755	4 30	6 00		
1783	7 51	7 00		
1797	9 12	7 00		
1806	7 52	7 00		
1830	6 27	6 00		
1842	6 21	4 00		
1861	3 56	3 00		
1880	1 00 W.	1 00 W.		

netic distributions. But confessedly Mr. Wilde's globes were only approximate imitations of the magnetic conditions of the earth, for it would have been possible to rearrange the distribution of magnetism by changes in the relative intensities of the two fields employed, namely, the internal electro-dynamic and the external electro-magnetic, and by variations of the amount of magnetizable matter in localities, as was done in a general way for the sea and the land areas. One of the most important uses of such a model will be to test the possibility of producing exactly the observed magnetic forces, by such relative adjustments as have been indicated. In this way, if the test proves to be practicable, we may perhaps be able to study carefully the history of the changes in the magnetism of the earth considered as a heteorogeneous inductor. If this is so then also the geologist may have some interest in taking account of its indications, as concerns the distribution and the relative powers of the ferruginous iron deposits, or any other metals affected by magnetic induction. For since we may assume that it is a symmetrical system which is gradually sweeping across the globe, then the arrangement of the magnetic forces at any station becomes at once some index to the constitution of the material in which the magnetism is temporarily lodged.

It has already been pointed out that there is some discrepancy between the total secular period derived from the march of the magnetarium at the above stations, that is 960 years, and the probable periods obtained from the course of the observations which have been made. The contention is that these

periods are not uniform, that different stations have very different periods, ranging from 250 years to 600 years, and that none of them are likely to be so great as 960 years. An inspection of the periods derived from observations suggests the view that they group themselves in sub-multiples of 960 years, some being about 480 years and others 240 years in length. Of course this question cannot be settled either way, because observations do not yet extend over more than a portion of the whole period of any station. Nor is it necessary to take for granted that the rate of change throughout the period is the same as for the observed arc; indeed, it is certain that this cannot be so. It is not evident that the graphic area as an indicator of the force at work is a single closed space, since it may readily be a space of two or three dependent areas, that is, the bounding curve may be a loop or a series of loops; and we know that the Atlantic agonic lines have shown more than one, perhaps two or three secular waves sweeping over the globe from east to west. Whatever may be the truth underlying all these facts, we may fairly hope that the magnetarium will be able to aid us in such a study, so that our knowledge may be advanced beyond the uncertain state in which it has so long been detained.

The most important contribution of this magnetarium is, however, a very much deeper matter than any of the details alluded to, because it implies an analysis of forces, which, if proven true after the application of all critical tests, must become fundamental among the laws of science. Laying aside the consideration of all imperfect data, we see that the magnetarium consists essentially of two magnetic fields rotating about one another. The first, that is the interior electrodynamic field, is formed by the winding of the current wires over the surface of the inner globe; the second, that is the electromagnetic field, is formed by winding the interior surface of the outer globe in a similar manner. For each of these we can substitute a magnetic sphere polarized along the axis of the windings. Thus if P is the pole of the inner sphere, and aa its windings, then for the wires we can analytically substitute the magnetic system whose axis of magnetization is PO; and if P′ is the pole of the outer sphere, and bb its windings, we can substitute for it the magnetic system P′O. Now, according to the magnetarium, it is the rotation of the system P′O about the system PO, at a certain rate, which causes the secular variation of the magnetic

forces. This is the key to the situation, and if this is not disproven it is clearly a fact of great importance.

Here the question arises, what is there in nature and in the history of the earth that can have produced such a system of primary forces. Mr. Wilde has constructed a physical theory, but I suspect that his critics will generally dissent from his hypothesis. He suggests that while the earth was without a crust, the whole chaotic mass rotated parallel to the plane of the ecliptic;

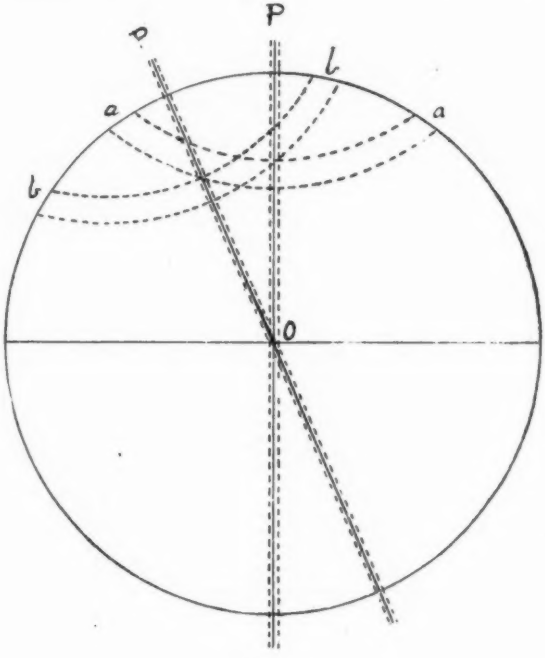


FIGURE I.

in its advanced stage of growth the interior of the earth retains its original plane of rotation, its electrodynamic forces being currents flowing in the planes of motion. These forces, he supposes, by general analogy with the sun, which does seem to exhibit electromagnetism, to be inherent in the heated vaporous condition of the original substances. This analogy may be plausible, but it certainly assumes the truth of many a

missing link, and will be accepted very cautiously. If the condition ended here the conclusion might appear less improbable. Yet we have to take another step and another hypothesis. The crust having been gradually formed became electromagnetic, which is doubtless perfectly true, but in some cataclysm was twisted about to rotate more rapidly in a plane differing from the first by $23\frac{1}{2}°$. This is very difficult to believe, and it is much harder to perceive how the energy or rotation in two such planes can be maintained, unless all the laws of friction, density and elasticity on the surface of the earth fail in its interior. Mr. Wilde's conclusion that it is as certain that the interior of the earth is liquid as that the globe rotates on its axis, will probably be read by astronomers and physicists with incredulity. The physical aspect of his model may have led him too far in his hypothesis, and it may be that he has not justly interpreted his own apparatus.

The subject is at this point on very difficult and delicate ground, arising from our ignorance of many of the essential characteristics of the nature of electricity, magnetism, and matter, in its static and its dynamic relations. What I have to say regarding, it, is with the utmost hesitation, and with the reserve allowed in scientific discussions, merely hoping to contribute something to what seems to me a most pressing problem. Is there any other way to explain the production of the two fields and their rotation about one another? In the *American Journal of Science* for September, 1891, p. 255, I wrote as follows, "There remains one more important point. The positive direction of the earth's permanent magnetism is from the north towards the south side of the ecliptic y, the uniform field is positive towards the sun z, the motion of the earth in its orbit x, is perpendicular to the field. If these are taken as the usual rectangular x, y, z, the form a consistent positive or right-hand cyclic system. In a word, the permanent magnetic condition of the earth may be principally due to the orbital motion of the earth through the radiant field of sunlight. The rotation of the earth on its axis causes a modification of the direction of the axis of polarization, by diminishing the angle between the two axes, and as the result of the annual motion may cause it to rotate in a secular period about the axes of figure, or if the magnetization has already become set in the body of the earth, may cause a succession of secular waves to sweep over it from east to west

as is shown to be the case in the history of the agonic lines and the long period deflections of the needle."

This statement was derived from a study of the diurnal variations of the needle at many stations, by which I find that the observed variations may all be accounted for by referring them to the field of the sun's radiant energy in the neighborhood of the earth's surface, and supposing that this field at the earth exhibits magnetic properties, as well as those we call heat, light and actinism. That the electromagnetic radiant energy of the sun should be broken up, upon impact with the earth, into many manifestations of energy, is the ultimatum of science, and that magnetic effects between it and the field about the earth should appear is not at all forcing the philosophy of the case. The complete data regarding these facts are being prepared, but we may now quote the figures which show these maximum magnetic effects, in certain definite planes relatively to the direction of the solar radiations.

Maximum magnetic deflecting forces, in units of the fifth decimal place (C. G. S.)

Fort Rae	.00096	C. G. S.
Kingua Fjord	100	" "
Point Barrow	123	" "
Jan Mayen	107	" "
Bossekop	107	" "
Sodankylä	62	" "
Wilhelmshaven	54	" "
Pawlowsk	36	" "
Vienna	38	" "
Tiflis	37	" "
Zi-ka-wei	6	" "

This table shows also some such relation as is displayed in the energy of the auroral system, and of the solar corona, by which there is a region of maximum force in the belts of the maximum of the auroral and the coronal displays, that is about 20° from the magnetic poles, as seen at Point Barrow, Jan Mayen, and Bossekop. The last six stations are not yet completely computed, and these figures are subject to revision.

If we may, therefore, be allowed to assume that the solar radiations are converted into magnetic forces in the presence of the field surrounding the earth, and that the lines of force of the earth's field may be regarded for analysis as the equivalents of certain wires which can be substituted for them, then by taking into consideration the astronomical motions of

the earth we have all the conditions, present for a dynamic induction. Expressing our idea in non-mathematical terms, it may be said that one field will be induced perpendicular to the plane of the ecliptic by the motion of the earth in its orbit; another field will be induced perpendicular to the plane of the equator, by the rotation of the earth on its axis; and by the annual motion of the earth carrying its axis parallel to itself about the sun, it will result that the equatorial field will revolve about the ecliptic field once in each year, so that we shall have the induction, as it were by magnetic precession, of one field upon the other. As I understand the magnetarium the field OP is the ecliptic field, OP′ the equatorial field, and these two fields being inclined to each other by $23\frac{1}{2}^\circ$ move one over the other in an annual period which may be on the whole equivalent to a differential motion of 22.°5, of the electrodynamic across the electro-magnetic field of the magnetarium, for each revolution of the outer globe.

The fact is recognized that we are in a subject of great difficulty, both practically and analytically, but it is thought to be of interest to know that from two totally different lines of investigation, namely, the diurnal variations and the secular variations of the forces of the field, we yet arrive at identical conclusions as to the general requirements of the problem. The mathematical analysis that will be developed from this cosmical problem gives evidence of being one of much intrinsic beauty, and it is hoped that we may before long be supplied with such data as will serve to check the formulæ and the computations.

March 7, 1892.

METHOD IN OUR WINTER TEMPERATURES.

By H. Gawthrop, Philadelphia, Pa.

In a study of the temperatures of warm and cold winters, in relation to the consumption of fuel, the writer has noticed that, when arranged in groups of different temperatures, there is a stiking uniformity in the progress of the seasons, a feature of which he cannot find any mention.

Of the many discussions as to the weather in which people indulge, there are none which excite more interest than the speculations as to what the coming winter will be and it is considered to be an open question even unto ground-hog day. Yet

with all due respect to that worthy, if the methods used in the figures and illustrations given below are correct, it would seem that the general character of the coming winter, as to temperature, is fore-ordained when the sun crosses the line at the autumnal equinox, and the direction then given is continued until late in the spring.

If we take the mean temperature at Philadelphia for the six coldest months of the year, November to April inclusive, since the first observations of the U. S. Weather Service in 1871, the average for the twenty years is found to be 38.9 degrees. It is found also that nine of these periods average above and eleven of them below that of the twenty years. In the table below, the averages and extremes of the mean temperature for the months of each group are given. For sake of brevity, they will be called warm winters and cold winters respectively. That our observations may extend over a longer period, we will add to the table the averages and extremes of the preceding Septembers and Octobers, and of the succeeding Mays and Junes.

TABLE I.

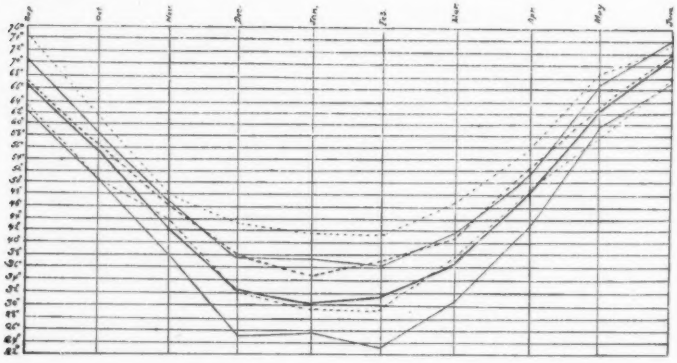
Monthly Mean Temperatures, Philadelphia, 1872-1891.

For nine warm winters.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
Highest	74.8°	61.4	48.0	43.6	41.8	41.4	46.4	55.6	68.3	73.6
Average	66.9	56.5	46.2	38.0	34.5	37.0	40.9	52.2	62.2	71.5
Lowest	63.6	50.4	43.8	32.2	29.4	29.5	37.6	48.7	57.3	67.8
For eleven cold winters.										
Highest	70.6°	58.2	46.5	37.8	37.4	36.1	40.9	51.3	66.7	73.9
Average	66.3	55.2	42.3	32.4	30.1	31.2	36.4	48.5	62.0	71.3
Lowest	62.6	50.4	38.0	25.1	25.8	23.4	30.8	42.6	59.6	67.1

The first chart gives a graphic view of these figures, the dotted lines showing the average and extremes of the warm winters, and the solid lines the average and extremes of the cold winters.

It will be seen that each group starts out in a channel well defined from that of the other, the lines gradually broadening until midwinter, and then as gradually approaching again, with a symmetry truly remarkable. If these lines are extended into the summers preceding and succeeding, the averages will be found to cross each other.

Taking the extremes into consideration, as we have done, would seem to guard against the deception of averages. The popular supposition is that a winter may commence extremely cold, or the reverse, but the record does not show that this is the case.



Group of nine warm winters average..... Extremes.....
" " eleven " " " " ..... " .....

To make further test, the twenty years are divided into three groups, as shown in the next table: seven with an average temperature for the six months above 40°; six between 38° and 40°, and seven below 38°.

TABLE II.

Monthly Mean Temperatures, Philadelphia, 1872–1891.

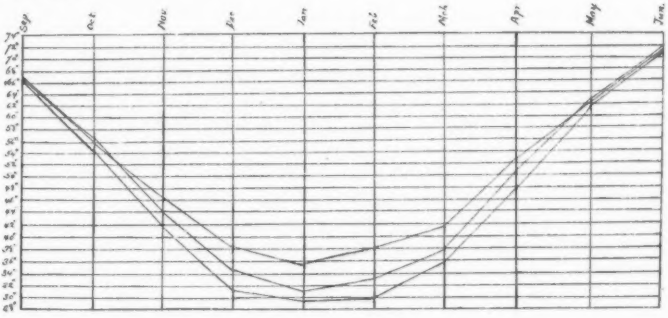
Averages.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
Seven winters above 40°..	66·8°	56.1	46.7	38.4	35.9	38.0	41.5	52.3	62.3	76.6
Six winters 38° to 40°.....	66.5	56.8	44.1	34.8	31.0	33.1	37.9	50.3	62.6	71.9
Seven winters below 38°..	66.4	54.6	41.5	31.4	29.2	29.9	35.8	47.8	61.3	70.7

These averages are shown in the second chart by the three

lines. It can surely be claimed that there is method and not chance in this result.

For comparison, and still further test, the records of the Pennsylvania hospital for twenty years from 1825 have been taken and arranged in groups of ten warm and ten cold winters. The result is almost identical, with the above, except in January, when not only the extremes, as shown in the first chart, but the average of the cold winters rises to meet that of the warm winters. Then the two groups continue with the same marked interval shown in the first illustration. This tendency upward would indicate that the "January thaw" is a special feature of cold rather than of warm winters.

This momentous ordering of the seasons may mean health or sickness; life or death to vast numbers; bountiful crops in one land and famine in another; activity or depression in the industry of the miner and factor who supplies fuel or clothing, and to commerce quick movement or stagnation in all the arteries of trade.



Group of seven winters above 40°.
" " six " between 38° and 40°.
" " seven " below 38°.

If a geologist should find strata as well defined as our cross-section of the winters, he would quickly, with little heed to many exceptions, assign it to some remote period as a conclusive fact. In meteorology, however, phenomenal temperatures, blizzards and floods are so prominent, as exceptions, that rules are disproved, and prophets, who reckon from past records, find that they are without honor.

We take courage, in this instance, to suggest that arrangement of periods in groups may give interesting results in the study of first and last frosts and of pressure.

ON ACCLIMATIZATION*

By Robert W. Felkin, M.D., F.R.S.E., Etc.

Read at Meeting of British Association, 1891.

For many reasons the subject of acclimatization is an important one, and its interest increases yearly. New areas are coming under European influence, and statesmen are naturally anxious to know of what use they will prove; whether they will only be useful in a strictly commercial sense, or whether colonization will be possible, and if so, where and to what extent? Again, the world's population is rapidly increasing, and, according to the paper which the President of this section, Mr. E. G. Ravenstein, read before this association in Leeds, last year, unless some great catastrophe happen, we may look forward to a time in the comparatively near future when the population of the world will be so great that it will be almost impossible to obtain subsistence, even should the whole area of the world become inhabited by an evenly distributed population.

During the last few years the subject of acclimatization has been frequently referred to. I would call to mind the paper read by Dr. A. Oppler before this Association in 1887; Mr. Ravenstein's paper on "The Lands of the Globe still available for European Settlement," read in 1890; a paper read by Sir W. Moore before the Epidemiological Society in January this year, "Colonization of Central Africa by Europeans;" a paper I myself read on the same subject at Birmingham in 1886; a paper published by Professor Virchow in the *Zeitschrift für Ethnologie*, 1885, accompanied by an important discussion in which Bastian and Fritsch took part, a communication on the "Acclimatisationsfähigkeit der Europaer in Asien," by Professor A. Sprenger, published in the same journal. The subject of acclimatization is also referred to by Herr Joest in a paper on his journey in Africa in 1883 (*ibid.*); and in 1886 various other important communications were published in the *Zeitschrift für Ethnologie*, viz.:—a paper by Dr. Beyfuss on "Die Acclimatisation der Europaer in Neiderlandisch-Indien;" one by F. Jagor on "Der Sterblichkeit der Eingeborenen und Europaer in Ost-Indien," which was followed by a discussion; and a very important paper by Dr. August Hirsch on "Acclimatization and Colonization." These are all I need mention.

* Scot. Geog. Mag., Dec. 1891.

I find it, therefore, very difficult to say anything fresh on the subject. This is my misfortune, not my fault; I would not myself have chosen to introduce this discussion, but, having been requested to do so, I will endeavor to indicate what acclimatization is, and what the difficulties of acclimatization are, and I must apologize if I only echo much that has been said before.

When we look at the opinions that have been expressed on the subject of acclimatization, we find that we can divide them into two schools of thought—one regarding acclimatization as impossible, which view is supported by Virchow, Hirsch, Fritsch, Ravenstein, and others. Without going into detail, they hold that Europeans can never become acclimatized in the full sense of the word in tropical regions, thinking that the deterioration caused by climatological factors and endemic diseases will invariably either kill off the emigrants, or at any rate render their ultimate existence impossible. Others, as De Quatrefages, hold that Europeans can become acclimatized anywhere. They, however, allow that the process of acclimatization will be accompanied by severe loss, and will only occur after several generations. Others again are far more sanguine, such as Livingstone and the late Bishop Hannington, who thought that rapid acclimatization in tropical regions is possible for Europeans. I may state at once my own view of the subject. It is that, although we have at the present day examples of nations who have become acclimatized in areas far from their original habitat, hundreds of years have been required, and an immense mortality has accompanied their migrations, and it has only been by a process of the survival of the fittest that this acclimatization has been possible at all. I believe, however, that our increased knowledge of climatology and of hygiene has rendered the problem more easy of solution. Given picked individuals, and the careful selection of tropical areas in which to colonize, I see no reason why, with precautions, Europeans should not colonize even in the tropics; if he

> "... Study well the clime,
> Mould to its manners his obsequious frame,
> And mitigate those ills he cannot shun."

I may mention in passing that a very careful selection would need to be made, and that persons with a tendency to gout or rheumatism, diabetes or albuminuria, those with a nervous or alcoholic family history, or those suffering from either acquired or hereditary syphilis, should certainly be rejected.

When speaking of the subject of acclimatization with reference to Europeans, we are very apt to fall into the error of imagining that all Europeans can be acclimatized or will resist acclimatization in any given area equally. This is undoubtedly a mistake, for a marked difference obtains between northern and southern Europeans in this respect, and not only the climatology of their original residence must be taken into account, but also their habits and customs and their physical peculiarities; and if these factors have to be considered with regard to the adaptability of a nation for emigration, so too with regard to the individuals of any nation. It is a fact that selected individuals from nearly every European nation may thrive almost all over the world. It has been denied that environment influences the human species, and it has been said that nations seek out that environment which is best suited for them. These statements I feel bound to deny, and I would say that environment definitely influences not only individuals but nations. This Herbert Spencer has shown in his "Principles of Biology," where he demonstrates that every organ and every function of living beings undergoes a certain and definite modification within certain limits under the stimulus of new conditions; and he further opines that this modification is almost always such as to produce an adaptation to a new environment.

Broadly speaking, it must be admitted that Europeans can only become readily acclimatized in the Temperate Zone, that is to say, where climatic and other conditions are approximately akin to their present habitat. We may say, too, that the people who inhabit the Temperate Zone become more easily acclimatized in countries towards the north of their present habitation; and this is shown by the fact, if we are to credit it, that during the past 2,000 years the Aryans have penetrated from the Tropics to the region of ice and snow within the Arctic Circle. Apart from this, however, as Mr. Ravenstein has shown, "if the white man is ever to occupy permanently the tropical parts of the world, it will have to be done by stages, each stage making a generation of men. We well know that the peoples of southern Europe, such as the Italians and southern Frenchmen, can better bear the climate of sub-tropical Africa than can northern Europeans. A steady stream of migration is, in fact, setting in that direction. Germans and Belgians are pouring into France, Frenchmen are going to Algeria, the Arabs from the shores of the Mediterranean have

found their way into the Soudan, whilst the Soudanese are pushing forward into Bantu Africa. A similar movement is going on in southern Africa. The descendants of those Dutchmen, who, a couple of hundred years ago, first settled at the Cape, have made their way to the Transvaal, and European migration, favored by geographical features, is being pushed even within the Tropics towards the Zambezi." With this I quite agree, and would once more call attention to the fact that wholesale, immediate acclimatization for Europeans in tropical regions is entirely out of the question.

There is little doubt that southern European nations would be able to colonize in the Tropics were the physical constitution alone to be taken into account; but temperature also plays a definite *rôle* in the possibility of prolonged existence in a given region, and it is a quality which especially requires time to be modified to new conditions of life. Hereditary temperament and capacity of mind variously characterize all nations, and differences of intellectual and moral power are well-marked factors in the possibility of acclimatization. It is these factors which to a great extent limit the power of southern Europeans to thrive in the Tropics, whereas northern Europeans, though physically less able to withstand tropical influences, are yet in possession of a more stable temperament and greater strength of character, which will go far to enable them to overcome the difficulties incident to a sojourn or a settlement in the Tropics.

The acclimatization of Europeans in the Tropics can only be successful if migration occurs step by step; and in estimating the possibilities of acclimatization we must count by generations rather than by years. In 1861, it is true, Dr. Hunt denied this, saying that "time is no agent," and "if there is no sign of acclimatization in one generation there is no such process." This, however, cannot be accepted, because there are many instances to prove the contrary.

What happens with regard to animals? We know that they can be acclimatized, and we know how their bodily structure is modified in order to enable them to adapt themselves to a new environment. It is not necessary to quote instances, they are so well known, but the following quotation from the last edition of the *Encyclopædia Britannica* shows the practical way in which an animal or plant may be acclimatized in a country very dissimilar from that of its native habitat, and where it has been

experimentally proved that the species in question cannot at once live and maintain itself:

"1. We must transport as large a number as possible of adult healthy individuals to some intermediate station, and increase them as much as possible for some years. Favorable variations of constitution will soon show themselves, and these should be carefully selected to breed from, the tender and unhealthy individuals being rigidly eliminated.

"2. As soon as the stock has been kept a sufficient time to pass through all the ordinary extremes of climate, a number of the hardiest may be removed to some more remote station, and the same process gone through, giving protection if necessary while the stock is being increased, but as soon as a large number of healthy individuals is produced, subjecting them to all the vicissitudes of the climate."

It is obvious that we cannot deal with men exactly in this way; yet there is no reason why robust and healthy individuals should not be chosen for experimental acclimatization, and why areas should not be sought out, even in the Tropics, where the climatological conditions are not altogether unfavorable to the success of the experiment. Such areas are to be found.

We must now try to ascertain what we know of the results of attempts at colonization by Europeans in the past. As Dr. Oppler pointed out at Manchester—"of eighty million Europeans and their descendants who live at the present time, no fewer than ten millions have found a home within the Tropics (or rather within the isothermal lines of 58° F.) Of these ten millions, fully nine millions live in Tropical America."

We find that the Dutch adapt themselves to a Tropical climate; they live quiet and temperate lives, dressing lightly, doing their work in the early morning hours, paying great attention to the drainage of the district they inhabit, and to their sanitary surroundings. At the Cape of Good Hope, where they have been, so to speak, isolated for the last 200 years, and where they have intermarried very slightly, they are tall and robust, they have retained their fair complexion, and, so far as physical development goes, we may say that they leave nothing to be desired. They marry at an early age, and their families are large. This is proved by the increase which has taken place, for we find that, whereas in 1798 they were under 22,000, in 1865 they numbered over 180,000. Again, we know that in

Tropical South America, Europeans have become acclimatized, and when the race is kept pure they seem to improve in all respects.

If we desire an example of a race thriving in extreme vicissitudes of climates, it is to be found in the Indians, who, coming from a temperate region in North America, have become acclimatized in the hot dry coasts of Peru, and also in the extremely cold regions of the Andes, at an altitude of from 4,000 to 6,000 feet. Now, notwithstanding that the inhabitants of these two regions do not thrive if they are removed from one to the other, they have nevertheless proved the possibility of an original race becoming gradually acclimatized in areas which are totally different from a climatological point of view.

As Professor Virchow pointed out in 1885, we have two questions to consider. The one is—Can an individual become acclimatized? the second concerns the acclimatization of a race. With regard to the first question, we have to ask How long can an average and healthy European withstand a foreign climate? To what extent can he become accustomed to it? For how long can he adapt himself to his new environment, and in what measure is he capable of manual labor there? In reference to the second question, we have to ascertain if, and how it is possible for, a European emigrant to found a family, and so to adapt himself and his children to his new environment that they can permanently exist there? These questions are by no means easy of answer. As to the first, it is perfectly true that some picked men removed from Europe to the tropics do particularly well. They do not suffer from the heat; malaria seems to have no power over them; they sleep well, notwithstanding the noises and nuisances of a tropical life; and we find, as Sir William Moore points out, that "some grow stout and some grow thin," and yet appear to adapt themselves individually to any climate. They experience good health, they are capable of any and every kind of work, and at a good old age they return to Europe apparently uninfluenced by the climatological vicissitudes to which they have been exposed. These individuals appear to possess more than the average of *vis vitæ;* and it is from them, in all probability, that the best Eurasians spring. Looking to India, I suppose it must be admitted that the Eurasians are not a degraded, miserable stock, but superior to their mothers in mental characteristics, they are also superior to their fathers in physical development, in staying-power, and in vitality. This

leads me to a remark, in passing, that it would be a great advantage were this class of Eurasians in India well cared for by the government, and were legalized marriages between the two races encouraged, and the children of such unions fostered.

Dealing next with our second question, we are met with insuperable obstacles in coming to even an approximate answer. The main difficulty rests with the want of statistics; and although we find in Cuba, for instance, and in Jamaica, that there is an apparent increase in the European population; yet we cannot be sure that this increase is due to the increase of the acclimatized individuals, or whether it is not a fallacious increase due to an incessant influx of southern Europeans. These are all points which I have only briefly touched upon in order to open the way for a discussion on the subject, and to elicit if possible definite and instructive data.

It is surely a sign of the times that even insurance companies are not now averse to taking the risk of a tropical residence. What would have been thought of an office fifty years ago which was willing to take such risks? Now, however, we find that one so important and well known as the "Standard" will insure men going to reside in India, Ceylon, the Straits Settlements, China (Shanghai, Hongkong, Peking, and all the treaty ports), Japan, West Indies, and the Mauritius. This office has stood the test of time, and it is impossible to suppose that its managers would enter into such business were they not sure that the time had come when the probabilities of life in the tropics were as capable of being estimated as they are at home. As a matter of course an "extra" is charged; but even so, it proves that residence in the tropics is not so uncertain, so fatal, as it once was. A well known actuary told me the other day that even with regard to the Congo Free State, he estimated that the extra to be charged was ten per cent. This "extra" is certainly heavy, but "coming events cast their shadows before."

It is unfortunate that in this investigation so much must rest on supposition and deduction, and that we have so few definite statistics to guide us. Even with regard to the Anglo-Indian army, we have only systematic sanitary reports since 1865; hence, in considering Indian statistics, and the light they throw upon the health of Europeans in that country, we can only take as approximate the figures at hand. This notwithstanding, we find undoubted evidence that the mortality of the troops in India has decreased remarkably in recent years. In 1820, the

annual loss per thousand was 80 (I take these figures from a paper published by Surgeon-General Sir William Moore); in 1856 the loss was 58 per thousand. But, as Sir William points out, "in those days men were not invalided home with the liberality which now obtains; and when ordered home for change, they had to wait perhaps months for a ship going round the Cape, for there were no Indian troopers, and the Suez Canal was not constructed. Yet invaliding at this period raised the total loss to the service to 69 per thousand." The average loss from 1870 to 1879 inclusive was,—invaliding 43 per thousand, the death-rate 19.34. This rate was still further decreased in the succeeding nine years ending 1888, when the average invaliding was 34 per thousand, the average death-rate 16.03. But, as Sir William Moore again points out, this rate of mortality and invaliding is still far too high, and depends chiefly upon the immature soldiers who are sent to India. Surely the short-service system has much to answer for in this connection, for it is an admitted fact that soldiers should not be sent to the tropics until they are fully mature, that is to say, between the ages of twenty-four and twenty-five.

However, the reduced death rate proves that much has been done to rob a residence in the tropics of its terrors, and, to my mind, it also indicates a time coming when science will render a more prolonged or permanent residence within the tropics a practical possibility.

Of course, it is climate which exerts the greatest influence on mankind. As Forray says, "Climate constitutes the aggregate of all the external physical circumstances appertaining to each locality in its relation to organic nature," or, in other words, H. T. Buckle says, "It is the influence exercised by physical laws over the organization of society, and over the character of individuals."

The salubrity of a climate depends generally and chiefly upon (*a*) a moderate and comparatively equable temperature, (*b*) on a certain dry condition of the soil, (*c*) as Mühry pointed out, "in a minor degree on certain unknown endemi-physical predispositions to peculiar morbid conditions."

In order to attain acclimatization in a hot climate we must have (*a*) an alteration in the quantity and quality of the blood to render it adapted to the needs of the individual (physiological anæmia). This can be, and usually is, attained in two years. (*b*) A climate is, we know, only healthy or unhealthy as

regards the individual, as may be briefly illustrated by Southern Europe being used as a health resort for phthisical patients; but in this connection races have a certain immunity from some diseases. Thus, negroes do not suffer excessively from malaria, provided they remain in their own districts; but should they be brought to Europe, cold tries them greatly. (*c*) We must also take into consideratlon that, in the tropics, some places are healthy, others unhealthy; for, as Lind said long ago, we can always, with due care, find comparatively healthy areas in any part of the world.

In considering tropical climates, with reference to health, we must not forget that although in some places the mortality is very high, it is so also in Europe, where we must take into account the various circumstances which influence the salubrity or otherwise of a district. Persons inhabiting large towns are liable to many factors which act towards deterioration, and there the death-rate is far higher than it is in country districts. If we compare the death-rates of the various capitals of Europe, we find that marked differences obtain; for insance, the death-rate in London is one-third less than that in St. Petersburg or Moscow.

It would add too greatly to the length of my paper were I to indicate all the facts known with regard to mortality in various European cities and countries. I would, therefore, only call attention to the certainty that, where sanitary precautions are properly carried out, the death-rate diminishes exceedingly; and, comparing those towns in the tropics which are under the influence of European knowledge, we find that the average rate of mortality compares very favorably with that of towns in Europe where sanitary precautions are less attended to.

It is curious to notice that, when Europeans proceed to countries possessing a very different climate from their own, their children in a generation or two, receive an indubitable impress from the climatological factors around them. Take, for instance, the Europeans who go to North America, and we find that they tend to approach in type to the original inhabitants of the soil. They outwardly resemble the North-West American Indians. The hair becomes straighter, coarser, darker; the cheek-bones become more prominent, and the rounded form of the face changes into the gaunt, lined face which is typical of the inhabitants of the United States. The skin takes on a sallow complexion, the voice itself changes, and the nasal twang so

apparent to Englishmen, becomes pronounced. Again, if we look at the residents in Australia, we find very peculiar results are induced there. Supposing, for instance, that a woman proceeds to Australia, having already given birth to three or four children, the children she subsequently gives birth to in the new climate do not resemble her previous progeny so much as they do the Australian type.

Further, granted that the Anglo-Saxon race can maintain itself, and become acclimatized, as in Australia, New Zealand, and America, is it not probable that the race may undergo such changes as materially to alter those qualities upon which the worth of the race, so-to-say, depends? Are not the *Cornstalks* of Australia, the Anglo-New-Zealanders, etc., practically different from their ancestors, and do not they severally indicate a tendency to change to an altogether new type of manhood with new aptitudes and capabilities? But this very interesting question cannot be further discussed.

We have also to consider what effect the liability or otherwise to disease has with reference to acclimatization. (*a*) A lengthened residence gives strangers a certain immunity from such diseases as dyspepsia, and all that wide class of disease which is induced by plethora. It may be, too, although the fact is denied by some authorities, that the longer a European resides in some portions of the tropics where yellow fever obtains, the less likely is he to suffer from that fever. (*b*) The probability of strangers suffering from certain diseases is heightened by the length of residence. For instance, a person is far more likely to suffer from malarial fever, and all those chains of symptoms induced by malarial intoxication, the longer he resides in a district where malaria is rife. In this connection, it must be noted that, although a person himself may be obnoxious to the influence of malaria, yet it is indisputably proved that his children will be susceptible in a very marked degree to the debilitating influence which malaria exerts upon the organism. (*c*) We must also not lose sight of the fact that there are certain diseases which strangers are only likely to suffer from after a prolonged residence in the tropics. This depends more or less upon the amount of cachexia affecting the individual, and such diseases as yaws or elephantiasis can only make their appearance in those who have resided for so long a time in the climate in which they are indigenous that certain climatological factors have so far impressed themselves upon

the individual that a predisposition to the disease is induced. With regard to these diseases, there is reason to hope that within a very few years a method of prophylactic treatment may be evolved which will prevent their occurrence at all. Indeed, with regard to elephantiasis, the researches which I have been able to make seem to show that it is a preventible, and even curable, disease. (*d*) There are, finally, certain diseases which only occur in children of the second generation. They occur after dentition, and are of an atrophic character. Up to the present time nothing has been done to control these diseases, yet I am convinced that if during pregnancy the mothers were properly treated, and if during the early years of child-life proper prophylactic medication were attended to, much might be done to save such children from the effects of environment and to fortify them so that they might bid defiance to the climatological factors which till now have either rendered their existence in the tropics impossible, or have induced such a state of constitutional debility as to necessitate a return to Europe in order that they should survive or be prevented from becoming sterile.

Looking at the factor of heat, we have to think whether it is a high mean annual temperature, or only a high temperature without any seasonal variation; because for Europeans, if we have a climate where the seasonal variation is 30° Fahrenheit, or over, we find that the people can do as well if not better than in Europe. In those places, however, where there is only a mean annual variation of 10° or 15° Fahrenheit, or where the diurnal variation is less than 10° Fahrenheit, immigrants cannot stand the climate. It is curious, no doubt, to speak of cold when dealing with acclimatization of Europeans in the Tropics; but cold exerts a great influence on the capability of withstanding a tropical climate. We find that in regions where, the mean annual temperature being equal, the diurnal variation is excessive, individuals from Europe cannot withstand this fluctuation; because, granted that a person is ready to perspire with the hot daily temperature, he cannot withstand the cold nightly variation which so often obtains.

With regard to endemic diseases, altitude undoubtedly plays a definite *rôle*: malaria, for instance, is far less virulent when we attain an altitude of about 3,000 feet; and with regard to yellow fever, we know that, at an altitude of over 1,000 feet, it can never exert epidemic virulence.

Summing up what we know respecting the heat, the cold, and the diurnal variation of temperature in the Tropics, we come to the conclusion that it is impossible for any European nation to become acclimatized *at once* in any tropical region; but we think that if the attempt be made step by step, generation by generation, it is not improbable that northern Europeans may become acclimatized in, say, 100 years, in Tropical India or Africa; and that if representatives of a nation were to endeavor to proceed gradually from a temperate to a tropical country, they might, in five or six generations, acclimatize themselves either to the north or to the south within 30° of their original habitat.

In conclusion, it must be admitted that the permanent residence of Europeans in tropical climates must be first attempted in those regions possessing a definite altitude — an altitude which will give them considerably less heat, less moisture, and a greater immunity from endemic diseases than low-lying plains.

CURRENT NOTES.

CORRIGENDA. — In the January JOURNAL, page 397, the statement is made that the meteorological station on Mount Washington was unoccupied during the year 1891. The station was, however, open last summer as during the three previous summers. A. L. R.

In Balloon Meteorology, February JOURNAL, page 466, second line from top, after "showed," *insert* "that a Richard thermograph records a temperature some 8° C."

"MAURY'S PHYSICAL GEOGRAPHY," Revised. University Publishing Company, New York, 1891. $1.40 introduction price.

This is a revised edition of Matthew Fontaine Maury's famous work, by his kinsman, the Rev. Dr. Mytton Maury. The "Physical Geography," as Commodore Maury himself said, had its origin in "the joint labor of his wife, daughters and self," as a means of home recreation during a residence abroad. As the best sources of information were kindly put at their service, and as Maury had also the combined knowledge and experience of fifteen years superintendency of the Washington Observatory, the undertaking was congenial, and the occupation for them

all a labor of love. And possibly in this very naturalness was the secret of the charming style with which we are all so familiar. The reviser has sought to preserve this wherever possible, but has simplified and abridged, most wisely, we think (if the book is to be considered from the standpoint of an educational text-book), some of the earlier views and explanations. He has added, too, a short account of the more recent of physical facts bearing upon physical geography, facts which the progress of science since 1872, the date of the first edition, has made essential in the instruction of children, if they are to properly comprehend the methods of work and tendencies of to-day. In the book before us, Chapter IV is the one devoted to meteorology, and therefore especially interesting to readers of the JOURNAL. It treats of the physical properties of the atmosphere, climate, prevailing winds, ocean currents and storms; not very deeply, to be be sure, but in, we think, a most interesting way. In the description of "tornadoes," for example, we could have wished for a little fuller discussion, and some little mention, perhaps, of Ferrel's reasoning, Davis's popular expositions, or Finley's statistics; but, on the other hand, we note with pleasure the introduction, on pages 84 and 85, of two typical weather maps. Some information upon the subject of weather maps, forecasts, storm movements, etc., has long been needed in popular educational text-books of this character. There is much in the book that will be of interest to older minds, as well as to the younger ones, for whom it is chiefly intended. A. M.

ROYAL METEOROLOGICAL SOCIETY. — The annual general meeting of this society was held on Wednesday evening, the 27th of January, at the Institution of Civil Engineers, Great George Street, S. W.; Dr. W. Marcet, F.R.S., vice-president, in the chair.

The report of the council for the past year showed the society to be in a very satisfactory position. In May the library and offices were removed to more commodious premises at 22 Great George Street. After defraying the cost of fitting up the new offices, and the increased rental, there still remained a balance in hand of $1,220. Thirty-four new Fellows were elected during the year, the total number on the roll of the Society now being 552.

Owing to the absence of the president, Mr. Baldwin Latham, M. Inst. C. E., through an attack of influenza, his address on

"Evaporation and Condensation" was read by the secretary.

The question of evaporation is of as great importance as the study of the precipitation of water on the face of the earth, as the available water supplies of the country entirely depend upon the differences between these two sets of observations. The earth receives moisture by means of rain, dew, hoar-frost, and by direct condensation. It loses its moisture very rapidly by evaporation. Although evaporation mainly depends upon the difference between the tensional force of the vapor due to the temperature of the evaporating surface, and the tensional force of the vapor already in the atmosphere, yet it is largely influenced by the movement of the air and by its dryness, or the difference between the dew point and the actual air temperature. Evaporation goes on at night so long as the water surface is warmer than the dew point. With sea water the evaporation is about 4½ per cent. less than with rain-water, while with water saturated with common salt the evaporation is 15 per cent. less than with rain-water.

In his experiments Mr. Latham used an evaporating gauge made of copper, one foot in diameter, and containing one foot in depth of water, which was floated by means of a hollow copper ring placed six inches distant from the body of the evaporator, and attached to it by four radial arms. This form of evaporator was found extremely convenient in carrying on all evaporation experiments. It was floated in a tank, four feet in diameter, containing thirty inches depth of water. During the period of thirteen years, from January, 1879, to December, 1891, this evaporator has never once been out of order or been interfered with in the slightest degree by frost.

Experiments were made with some five-inch evaporators as to the effect of color on the amount of evaporation, one being painted white, another black, and the results given by these gauges were compared with a copper gauge exposed under similar conditions. This comparison was the means of showing that the greatest errors in evaporating gauges arise from the capillarity of the water rising on the sides of the gauge and thus inordinately increasing the amount of evaporation. Consequently a small gauge, having a larger amount in proportion of side area than a larger gauge, gives a very much greater amount of evaporation.

The results from the floating evaporator, one foot in diameter, show that the average amount of water evaporated annually

during 1879–'91 was 19.943 inches. It was found, however, that, as a rule, during the period from October to March, there were certain occasions when condensation was measured. The amount of these condensations in thirteen years averaged .308 inch per annum. The five-inch evaporating gauge, freely exposed to atmospheric influences, gave during the same period (1879–'91) an average annual depth of evaporation equal to 38.185 inches.

The average annual evaporation, during the three years 1879–'81, from the five-inch copper gauge standing in water was 27.90 inches, from one painted black 22.97 inches, and from another painted white 21.74 inches, whilst a gauge of the same dimensions, freely exposed in the atmosphere, gave, in the same period, 36.96 inches, and the one-foot floating evaporator, 19.40 inches. The five-inch copper gauge gave a larger amount of evaporation than the gauge painted black.

Mr. Latham next described some percolation experiments which were carried out by Mr. C. Greaves at Old Ford, by Messrs Dickinson and Evans at Hemel Hempstead, and by Sir J. B. Lawes and Dr. Gilbert at Rothamsted. He then detailed the results of his own experiments, and also the gaugings of the underground waters in the drainage areas of the rivers Wandle and Graveney.

He further stated that in the course of his observations on the flow of underground water, he had observed that at certain particular seasons of the year it was possible to indicate the direction and volume of the flow of underground streams, even when they were at a considerable depth, owing to the formation of peculiar lines of fog.

Dr. C. Theodore Williams was elected president for the ensuing year.

EDITORIAL NOTE.

With the end of the current volume this JOURNAL will pass into other hands. The managing editor will be Mr. Robert De C. Ward of Harvard University, Cambridge, Mass., and the publishers, Ginn and Company of Boston, Mass. Contributors to the new volume will hereafter kindly correspond with Mr. Ward. The present volume ends with this (the April) number, and this is now so nearly full that it would be well for all who propose to contribute to address themselves to him. In all business

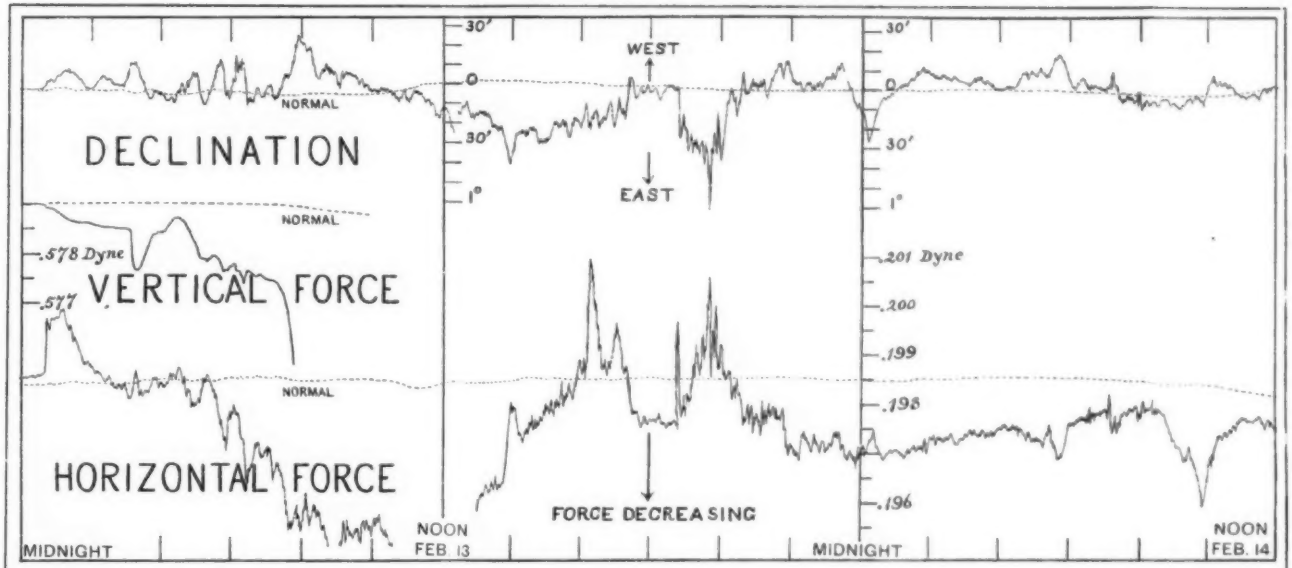
matters relating to the eighth or preceding volumes correspondence should be addressed to Mr. S. A. Moran, Ann Arbor, Mich., and such matters relating to the ninth volume should be addressed to Ginn & Company.

It gives us great pleasure to be able to make this announcement as we are sure the JOURNAL will be a success under its new managers. We bespeak for them the hearty sympathy and co-operation of our friends and hope they will gain many new ones.

MARK W. HARRINGTON,
A. LAWRENCE ROTCH,
W. J. HERDMAN.
S. A. MORAN.

Mr. Harrington and Mr. Rotch will remain on the editorial staff which it is hoped to enlarge by the addition of some well known writers.

(From the Pilot Chart of the North Atlantic Ocean, March, 1892.)



THE MAGNETIC STORM OF FEBRUARY 13–14, 1892.

Record of the Self-registering Magnetic Instruments at the U. S. Naval Observatory, Washington, D. C.

The above records of this unusually severe magnetic storm are of especial interest as occurring at the same time as the fine displays of auroræ and the appearance of a large group of sun spots.

The magnetic storm commenced suddenly at 12.40 a. m. (75th meridian time), Feb. 13, with a movement of the North end of the declination magnet to the westward and a rapid increase in the horizontal and decrease in the vertical components of the earth's magnetic force.

The North end of the declination magnet remained to the westward of its normal position until 10.30 a. m., when it crossed to the eastward, all the time oscillating violently, and did not return to the normal until 8 p. m. of the 13th, after which it kept oscillating on each side of its mean position until the end of the storm. It registered a change of direction of 1½°.

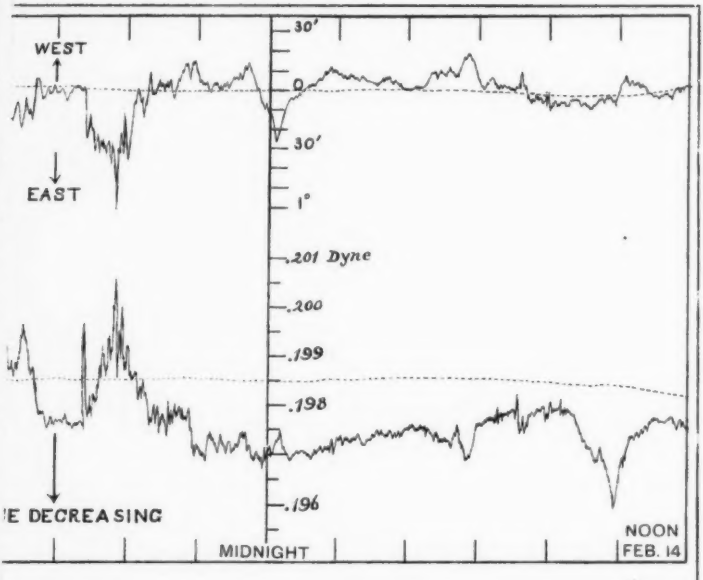
The first increase in the horizontal force was followed by a rapid decrease, the force falling to much less than its usual strength, with rapid changes. Its change during the storm was 2½ per cent. of its mean strength. The vertical force decreased so much that the sensitive balanced magnet used to record it was upset at 8 p. m. of the 13th, and its further record lost.

The auroræ were seen at Washington at about 2 a. m. and 7.30 p. m. of the 13th, the latter time being marked by an unusually disturbed condition of the magnets.

Division of Marine Meteorology. H. M. Witzel, Lieut., U. S. N. *Marine Meteorologist. Everett Hayden.*

Published at the Hydrographic Office, Bureau of Navigation, Navy Department, Washington, D. C.
Richardson Clover, Lieutenant Commander, U. S. N., Hydrographer.

e North Atlantic Ocean, March, 1892.)



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